

# Deep Learning based Framework for In-Vivo Identification of Glioblastoma Tumor using Hyperspectral Images of Human Brain

## Supplementary Material

**Table S1.** Detail of the total number of pixels of each class per patient and image of the HS labeled dataset.

Patient ID*	Image ID*	#Labeled Pixels				Diagnosis
		NT	TT	HT	BG	
1	2	5,007	0	965	1,992	Normal Brain
2	1	6,061	0	1,727	20,483	Normal Brain
3	1	7,714	0	1,089	0	Normal Brain
4 (1)	1	2,295	1,221	1,331	630	GBM
	2	2,187	138	1,000	7,444	GBM
5	3	10,626	0	2,332	3,972	Normal Brain
6 (2)	1	4,516	855	8,697	1,685	GBM
	2	6,553	3,139	6,041	8,731	GBM
7	1	1,827	0	129	589	Normal Brain
8	1	0	30	64	1,866	GBM
9 (3)	1	1,251	2,046	4,089	696	GBM
10 (4)	1	3,970	0	246	12,002	Normal Brain
	2	349	0	0	2,767	Normal Brain
	3	603	0	234	1,696	Normal Brain
	4 (1)	1,178	96	1,064	956	GBM
	5	2,643	0	452	5,125	Normal Brain
11 (5)	1	1,328	179	68	3,069	GBM
12	1	13,450	0	488	9,773	Normal Brain
	2	4,813	0	958	5,895	Normal Brain
13	1	6,499	0	1,350	1,933	Normal Brain
14 (6)	1	1,842	3,655	1,513	2,625	GBM
15	1	3,405	0	793	5,330	Normal Brain
	2	2,353	0	555	2,137	Normal Brain
	5	969	0	1,637	1,393	Normal Brain
16	1	2,806	0	1,064	3,677	Normal Brain
	2	8,174	0	680	0	Normal Brain
<b>Total</b>	<b>26</b>	<b>102,419</b>	<b>11,359</b>	<b>38,566</b>	<b>106,466</b>	<b>258,810</b>

<sup>†</sup> (NT) Normal tissue; (TT) Tumor tissue; (HT) Hypervascularized tissue; (BG) Background.

\*The number in brackets corresponds with the identifier of this patient and image in the test database.

**Table S2.** Average results of the leave-one-out cross-validation of the binary dataset obtained for each classification approach using the bootstrapping method with the 95% confidence interval.

	Average [95% Confidence Interval]			
	AUC	Accuracy	Sensitivity	Specificity
1D-DNN	0.99 [0.99, 0.99]	0.94 [0.94, 0.94]	0.88 [0.88, 0.88]	1.00 [1.00, 1.00]
2D-CNN	0.97 [0.97, 0.97]	0.88 [0.88, 0.88]	0.76 [0.76, 0.76]	1.00 [1.00, 1.00]
SVM RBF Opt.	0.97 [0.97, 0.97]	0.84 [0.84, 0.84]	0.68 [0.68, 0.68]	1.00 [1.00, 1.00]
SVM RBF Def.	0.86 [0.86, 0.86]	0.73 [0.73, 0.73]	0.58 [0.58, 0.58]	0.88 [0.88, 0.88]
SVM Linear Opt.	0.99 [0.99, 0.99]	0.77 [0.77, 0.77]	0.54 [0.54, 0.54]	1.00 [1.00, 1.00]
SVM Linear Def.	0.86 [0.86, 0.86]	0.68 [0.68, 0.68]	0.49 [0.49, 0.49]	0.88 [0.88, 0.88]

**Table S3.** Average accuracy results of the leave-one-out cross-validation of the four-class dataset obtained for each classification approach using the bootstrapping method with the 95% confidence interval.

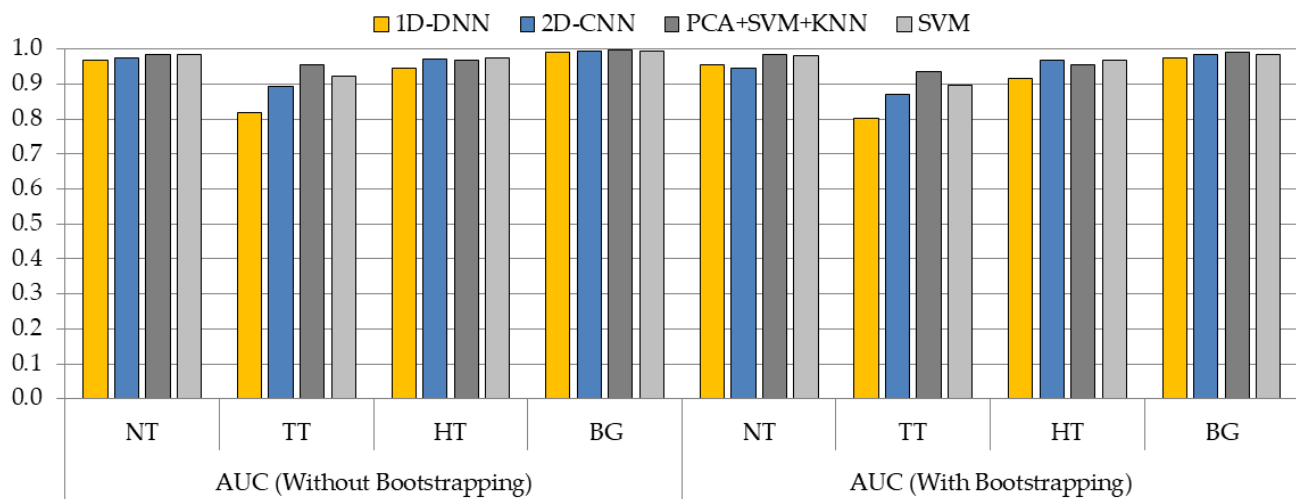
	Average Accuracy [95% Confidence Interval]				
	Overall	Normal	Tumor	Hypervascularized	Background
Proposed	0.80 [0.78, 0.81]	0.90 [0.86, 0.93]	0.42 [0.39, 0.45]	0.90 [0.92, 0.89]	0.98 [0.98, 0.98]
1D-DNN	0.77 [0.75, 0.78]	0.92 [0.88, 0.95]	0.42 [0.39, 0.45]	0.90 [0.92, 0.89]	0.83 [0.82, 0.85]
2D-CNN	0.77 [0.76, 0.78]	0.88 [0.86, 0.89]	0.40 [0.38, 0.42]	0.87 [0.88, 0.86]	0.93 [0.93, 0.94]
PCA+SVM+KNN	0.78 [0.76, 0.79]	0.96 [0.93, 0.97]	0.25 [0.23, 0.28]	0.92 [0.93, 0.90]	0.99 [0.97, 0.99]
SVM Linear Def.	0.77 [0.76, 0.78]	0.95 [0.92, 0.97]	0.26 [0.23, 0.29]	0.91 [0.93, 0.90]	0.96 [0.94, 0.97]

**Table S4.** Average AUC results of the leave-one-out cross-validation of the four-class dataset obtained for each classification approach using the bootstrapping method with the 95% confidence interval.

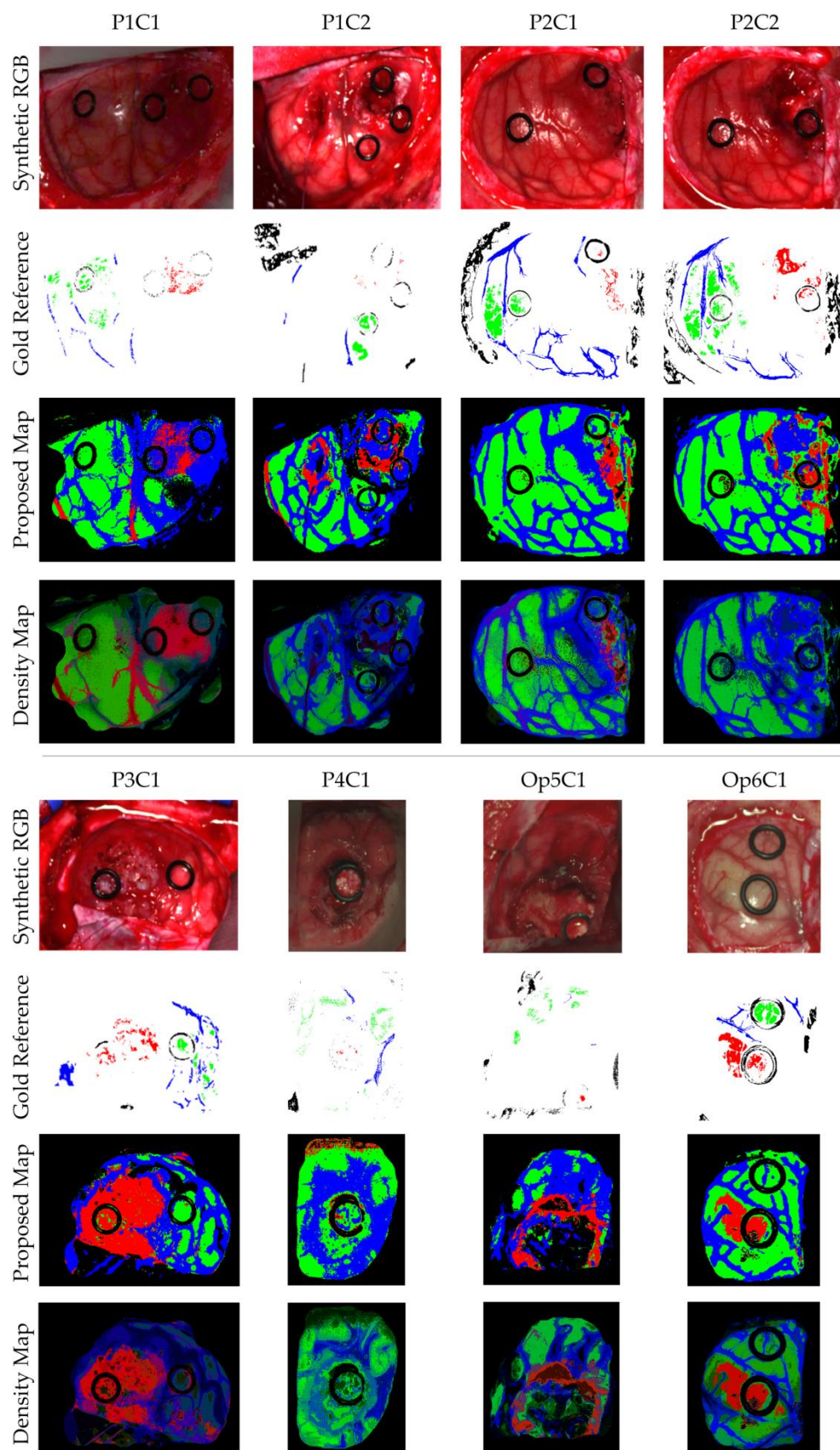
	Average AUC [95% Confidence Interval]			
	Normal	Tumor	Hypervascularized	Background
1D-DNN	0.96 [0.95, 0.96]	0.80 [0.78, 0.83]	0.92 [0.91, 0.92]	0.97 [0.97, 0.98]
2D-CNN	0.95 [0.94, 0.95]	0.87 [0.86, 0.88]	0.97 [0.96, 0.97]	0.98 [0.98, 0.99]
PCA+SVM+KNN	0.98 [0.98, 0.99]	0.94 [0.92, 0.95]	0.96 [0.95, 0.96]	0.99 [0.98, 0.99]
SVM Linear Def.	0.98 [0.98, 0.99]	0.90 [0.88, 0.92]	0.97 [0.96, 0.97]	0.99 [0.98, 0.99]

**Table S5.** Average AUC results of the leave-one-out cross-validation of the four-class dataset obtained for each classification approach with and without the bootstrapping method.

	Average AUC (Without Bootstrapping)				Average AUC (With Bootstrapping)			
	Normal	Tumor	Hyper.	Background	Normal	Tumor	Hyper.	Background
1D-DNN	0.97	0.82	0.95	0.99	0.96	0.80	0.92	0.97
2D-CNN	0.98	0.89	0.97	0.99	0.95	0.87	0.97	0.98
PCA+SVM+KNN	0.99	0.96	0.97	1.00	0.98	0.94	0.96	0.99
SVM Linear Def.	0.99	0.92	0.97	1.00	0.98	0.90	0.97	0.99



**Figure S1.** Average AUC results of the leave-one-out cross-validation of the four-class dataset obtained for each classification approach with and without the bootstrapping method. Graphical comparison.



**Figure S2.** Synthetic RGB image, gold reference map and classification results obtained for each test image using the proposed deep learning framework.